



Jet Propulsion Laboratory
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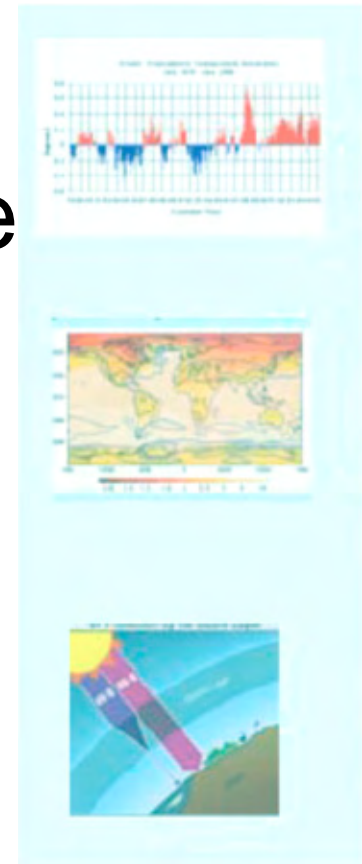
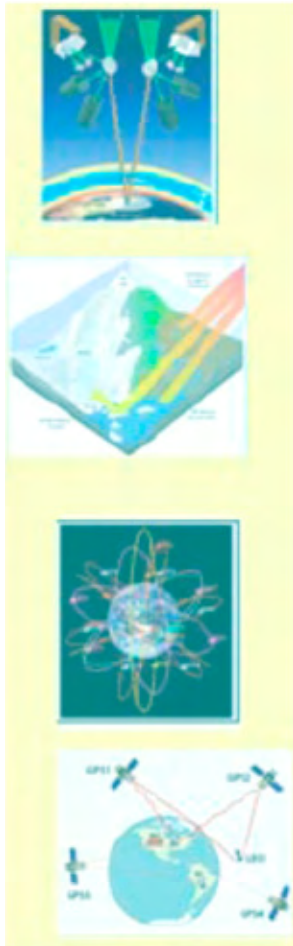
CLARREO: From a NASA Mission Architecture Perspective

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Contributions:

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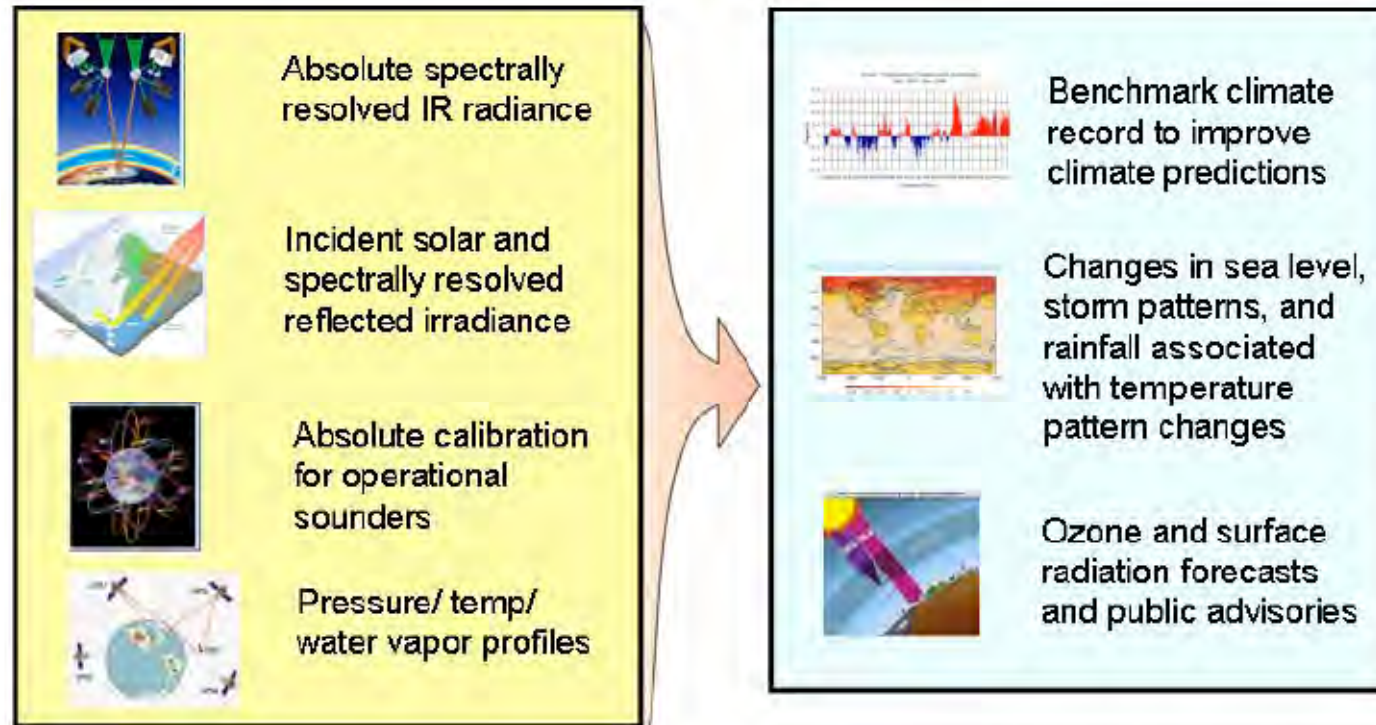
James Smith



Science Goals

Source: Decadal Survey

Key climate observations obtained globally from space



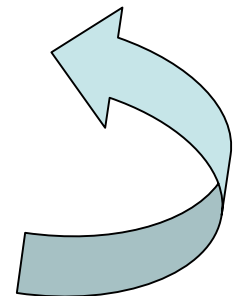
The Climate Absolute Radiance and Refractivity Observatory (CLARREO) will provide a benchmark climate record that is global, accurate in perpetuity, tested against independent strategies that reveal systematic errors, and pinned to international standards.

Mission Architecture Process

Architecture preparation is needed to formulate an optimal, consistent and realizable set of Science and Mission Objectives for a desired science investigation

An iterative process:

- Capture mission objective, science goals, science requirements; and sponsor's mission constraints (e.g., mission cost)
- Develop candidate architectures and ROM costs
- *Iterate – refine mission objective, science goals, science requirements*



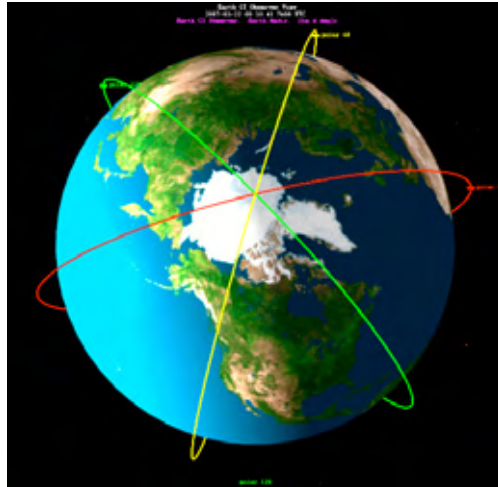
Pre-Workshop Efforts

- Investigate high-level mission architecture options to aid CLARREO science discussions and requirements refinement
 - Develop architecture options based on Decadal Survey goals and requirements
- Identify areas for discussion where further definition will enable mission architecture refinement
 - Identify key mission attributes, which drive mission implementation

CLARREO NASA Mission Concept

KEY MISSION ATTRIBUTES

Orbital Concept



Mission Concept

- **Benchmark accuracy of radiance climate measurements**
 - 0.1 K brightness temperature accuracy
 - Tied to NIST standards
- **Spacecraft: 3 small satellites**
- **Launch Date: 2010 - 2013**
- **Orbits: Three true 90° polar with a 60° angular separation between planes at 750 km altitude**
- **Mission Duration: 3 years nominal**
- **Goal: extension into lengthy operational mission**

Mission and Science Objectives

Climate Benchmarking

- Observe radiative forcing from greenhouse gases, aerosols, and clouds; and radiative response affecting atmospheric temperature, water vapor and cloud distribution through IR Earth-emitted radiance measurements
- Observe climate changes in snow cover, sea ice, land use, aerosols, and cloud properties through reflected solar radiance measurements

Observation Calibration/Validation

- Observe temperature and water vapor and determine systematic error in the climate record by observing atmospheric refraction with GNSS radio occultation
- **Serve as a high accuracy calibration standard for use by operational sounders on-orbit**

Instrument Summary

All 3 spacecraft carry:

Redundant IR Interferometers

- SI-traceable standard for absolute radiance
- 200-2000 cm^{-1} , 1 cm^{-1} spectral resolution
- **High level of absolute radiometric calibration**

GPS: occultation GNSS receiver

- Accurate to 0.1 K traceable to SI standards on-orbit
- Limb sounding to profile refractive properties of atmosphere

1 spacecraft ALSO carries:

Redundant UV/VIS/NIR interferometers

- SI-traceable standard for absolute radiance
- 300-2000 nm, 15 nm spectral resolution

Key Mission Attributes

Mission Attributes Taken From Decadal Survey	Impact on Mission Implementation
3 Small Satellites	<ul style="list-style-type: none"> • Requires procurement of three satellite buses • Impacts either number of launch vehicles or acceptable bus configurations
90° polar; 60° orbital plane separation at 750 km altitude	<ul style="list-style-type: none"> • Lessens possibility for flying instruments on other Earth science platforms • Non-sun-sync orbits drive thermal and power requirements, can impact instrument stability • Separation of orbital planes requires separate launches or potentially relatively large propulsion systems to achieve desired orbits (see poster) <ul style="list-style-type: none"> – Length of time to reach observing configuration
Each Instrument is duplicated (x2) per Spacecraft	<ul style="list-style-type: none"> • Increases mission cost • Drives power, mass and volume requirements
< 0.1 K Instrument Radiometric Accuracy	<ul style="list-style-type: none"> • Drives instrument design • Drives spacecraft thermal and sun orientation requirements
Absolute Radiometric Cross-Calibration of IR Sensors	<ul style="list-style-type: none"> • Drives the cal/val program • Drives instrument design • Drives orbit considerations
Far infrared	<ul style="list-style-type: none"> • Drives instrument cost (technology readiness and possible detector cooling) • Drives power requirements on instrument and spacecraft

Key Mission Attributes (cont'd)

Mission Attributes Taken From Decadal Survey	Impact on Mission Implementation	Science Impact of Modifying Requirements
3 Small Satellites	<ul style="list-style-type: none"> Requires procurement of three satellite buses Impacts either number of launch vehicles or acceptable bus configurations 	<p>To be determined by Science Community</p> <p>Workshop breakout groups are part of this process</p>
90° polar; 60° orbital plane separation at 750 km altitude	<ul style="list-style-type: none"> Lessens possibility for flying instruments on other Earth science platforms Non-sun-sync orbits drive thermal and power requirements, can impact instrument stability Separation of orbital planes requires separate launches or potentially relatively large propulsion systems to achieve desired orbits (see poster) <ul style="list-style-type: none"> Length of time to reach observing configuration 	
Carrying Two of Each Instrument per Spacecraft	<ul style="list-style-type: none"> Increases mission cost Drives power, mass and volume requirements 	
< 0.1 K Instrument Radiometric Accuracy	<ul style="list-style-type: none"> Drives instrument design Drives spacecraft thermal and sun orientation requirements 	
Absolute Radiometric Cross-Calibration of IR Sensors	<ul style="list-style-type: none"> Drives the cal/val program Drives instrument design Drives orbit considerations 	
Far Infrared	<ul style="list-style-type: none"> Drives instrument cost (technology readiness and detector cooling) Drives power requirements on instrument and spacecraft 	

Mission Attributes for Discussion

Can the CLARREO mission objectives possibly be met with alternative mission implementations?

Open Questions to the Working Groups:

- a) How firm is the requirement for 0.1 K accuracy (What are the science impacts if this is relaxed)?
- b) What type of redundancy is required to achieve science objectives? (Is this for risk reduction or to meet science objectives?)
- c) Is there flexibility in orbit choice?
- d) Can we achieve science objectives with < 3 spacecraft?
- e) What pointing control, stability and accuracy is required? Is a gravity gradient approach sufficient?
- f) What is the level of necessary calibration for the IR Interferometers, other interferometers?
- g) How firm is the requirement to use CLARREO to calibrate other sounders? (And what are the science and instrument requirements to achieve that?)
- h) What partnerships and/or other available asset utilization can we pursue?

We are here to help provide perspective on how different mission science and instrument requirements will drive mission implementation, cost and technology risk